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REMELTING THE HIGH-CARBON FERROCHROME DUST IN A DIRECT CURRENT ARC FURNACE (DCF)

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The paper describes the results of pilot remelting of high-carbon ferrochrome dust in a 1.8 MVA DC arc furnace. Standard grades of high-carbon ferrochrome, such as FeCh800, FeCh850 and FeCh900, were obtained with the following furnace performance: chrome extraction - 89,5 %; slag ratio - 0,5; specific power consumption - 2 272 kW·h/ton.

Keywords: high-carbon ferrochrome, metal dust, DCF, product

INTRODUCTION

The bulk of chromium alloys produced at Aktobe Ferroalloy Plant (AFP) is high-carbon ferrochrome grades, such as FCh-800, FCh-850 and FCh-900. High-carbon ferrochrome (HCFC) is smelted in submerged-arc furnaces with a capacity of 21 to 72 MVA. The melt from the furnaces is fed to casting ladles for casting into 2 ton ingots. After cooling, the ingots are transferred to the finished product shop for crushing in jaw crushers [1-6].

At the request of consumers, the alloy is crushed and screened into various classes, from 5 to 80 mm. Due to high carbon content (7 - 9 %) in the metal, the crushing of ferrochrome produces a large amount of a fine fractions. Metal dust, amounting to 3 % of total metal output, is collected by dedusting units [7].

RESEARCH METHODOLOGY

The objective of present study was to develop the technology and determine the technical and economic efficiency of remelting the bulk dust from HCFC crushing in a Direct Current Arc Furnace (DCAF) of the DCAF-1 type with a nominal power of 1,8 MVA.

Dust is the HCFC crushing and screening product, with a particle size below 1 mm. The dust contains 64 – 70 % of chrome metal, and the annual total output of dust is about 2 thousand tons. The nature of fine classes of dust increases the likelihood of their irretrievable losses during storage and transportation. Processing the dust into commercial products is a crucial part of a bigger problem – utilization of industrial wastes in the metallurgy [8]. The chemical and technical compositions of initial materials for remelting are shown in Tables 1-3.

Table 1 **Particle size distribution of dust**

Size / mm	+0,2	+0,16-0,2	+0,125-0,16	+0,071-0,125	-0,071
%	0,07	0,14	0,31	2,75	96,65

Table 2 **Technical composition of coke / wt.%**

Fixed carbon (C_f)	W	A	V	S	P
69,46	15,0	13,2	1,85	0,435	0,055

Table 3 **Chemical composition of charge materials / wt.%**

Material	Composition				
Dust	Cr	Si	C	S	P
	67,1	2,3	8,1	0,041	0,01
Ferrochrome slag	Cr_2O_3	SiO_2	MgO	Al_2O_3	CaO
	3,9	21,8	44,2	24,5	0,55

From the literature [9] it is known that much less metal and slag evaporates during melting in DCAF, 6 - 8 times less dust is formed, therefore, metals and alloys with a relatively low melting point can be melted in it. Besides, DCAF also has other advantages compared to conventional AC submerged arc furnace (SAF):

- ✓ reduced consumption of graphite electrodes (up to 0,8 - 1,5 kg/t);
- ✓ higher metal output due to reduced metal loss by 3 - 4%;
- ✓ lower ferroalloy consumption by 15 - 20 %;
- ✓ lower gas cleaning costs due to reduced dust emissions;
- ✓ noise level reduced by 15 dB;
- ✓ stability of electric parameters;
- ✓ electromagnetic stirring of liquid metal is possible.

RESULTS RESEARCH

Technology research on HCFC making by remelting was carried out in a semi-industrial DCAF with a transformer capacity of 1,8 MVA belonging to Aktobe State

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University. This is a closed-type furnace, equipped with one top graphite electrode and one hearth electrode. Combined tapping of smelting products is carried out by tilting the furnace with a hydraulic drive towards the tapping spout. Distinctive advantage of the furnace is its suitability for fine fractions of charge materials. A steel mold similar to the ones installed in the Smelting Department of AFP, was used for pouring and cooling of the melt. The working layer of the furnace lining is made of magnesite refractory.

The heating was made with coke, for which 5 kg of coke was fed under the electrode. As coke was consumed, the slag of high-carbon ferrochrome was fed into the furnace bath. After a three-hour heating, the furnace was switched off and the entire melt was tapped from its bath [9].

Assessment of specific consumption of electrodes for ferrochrome smelting.

Since slipping and nippling of electrode were not performed in every work shift, and the amount of metal varied significantly with each tapping, the specific electrode consumption was determined by the average data for the entire test period. The electrode consumption was determined by the electrode weighting before and after the smelting, with consideration of the nippled electrodes. Thus, over the entire smelting period the electrode consumption was 82 kg, i.e. 9,7 kg per 1 ton of ferrochrome, furnace heating period included. Specific consumption for the smelting period, without heating, amounted to 5,6 kg per 1 ton of ferrochrome [10].

Assessment of specific power consumption for dust remelting.

Data on specific power consumption for the entire smelting campaign are shown in the Table 4.

Table 4 **Specific power consumption for ferrochrome smelting**

Duration of furnace work hours	Metal amount / kg	Specific power consumption per campaign Wh / t
40	8 455	2 272

Assessment of DCAF-1 productivity for ferrochrome smelting.

Table 5 shows consumption of raw materials and products output per work shift.

Table 5 **Consumption of raw materials and metal output**

Shift	1	2	3
Input kg:			
Dust	3 200	3 300	3 530
Slag	260	420	540
Coke	47,5	22	57,5
Output kg:			
Metal	2 600	2 400	3 455
Slag	802	665	1 164

As per the Table 5, the furnace productivity increases sharply in the third shift at approximately even dust input. This can be explained by the fact that in the third shift the furnace began to work stably, i.e. entered the mode “correct furnace operation”. It is assumed that to determine the optimal technical and economic indicators of melting, a larger amount of dust is required, since 10 tons of dust is insufficient for continuous stable operation of the furnace.

Technical and economic indicators of ferrochrome smelting are given in Table 6. The chemical composition of the smelting products is shown in the Table 7.

Complete recovery of all dust and slag elements was achieved in the smelting campaign, the average chromium recovery was 89,5 %.

Table 6 **Performance characteristics of ferrochrome smelting in 1,8 MVA DC furnace**

No.	Parameters	
1	Charge input kg:	
	Dust	9 930
	HCFC slag	1 220
	Coke	140
2	Metal output kg	8 455
3	Slag output kg	2 631
4	Chemical composition of metal %	
	Cr	71,0
	Fe	20,0
	Si	0,61
	C	8,09
	S	0,03
	P	0,02
4	Furnace output kg/day	2 850
5	Average tapping weight kg	3 310
6	Cr extraction %	89,5
7	Specific power consumption kWhour/t	2 272

As can be seen from Table 7, the level of chromium oxide in the slag exceeds the standard limits of 3 - 7 %. This occurs mainly due to loss of metal into slag, as both products are tapped simultaneously from the same taphole, mixing in the mold. The speed of furnace tilting is constant and cannot be altered. The steel mold holding the melt is shallow, with depth of only 10 cm. Under such conditions, rapid heat dissipation promotes fast crystallization of ingot. As a result, drops of metal become entangled in slag as it crystallizes, making further separation very difficult where Table 8.

Such loss of metal, caused by pouring conditions, can be easily prevented at the commercial stage of dust utilization [11].

Metal from the test smelting was collected and sent to crushing. Screening data are presented in the Table 9.

As can be seen from Table 9, the output of fines below 10 mm is 16,5 %, which is much lower than average for commercial ferrochrome production.

The residual of the total material balance is 8 %, which is rather high. Manual charge feeding with shovels could cause substantial loss of material. Added to dusting during transportation and feeding, this could explain high balance residual.

From practical experience we know a method of packed charge feeding. The charge mixture is packed in

Table 7 **Detailed chemical composition of the smelting products / %**

Metal					
№	Cr	Si	C	S	P
1	2	3	4	5	6
1	70,3	0,4	7,5	0,01	0,02
2	72,3	0,4	8,0	0,03	0,01
3	68,9	1,0	7,9	0,04	0,02
4	71,8	0,4	8,2	0,03	0,02
5	71,1	0,4	8,5	0,05	0,02
6	70,8	0,5	8,0	0,04	0,02
7	71,8	0,5	8,4	0,03	0,02
8	71,0	0,5	8,4	0,03	0,02
9	70,6	0,7	8,4	0,03	0,02
10	70,4	0,4	8,2	0,04	0,02
11	70,5	0,5	8,3	0,04	0,02
12	70,7	0,4	8,3	0,04	0,02
13	70,7	0,7	8,1	0,05	0,03
14	70,9	0,8	7,5	0,05	0,03
15	72,6	0,7	8,0	0,03	0,02
16	71,1	1,1	8,1	0,03	0,02
17	71,3	0,9	7,7	0,01	0,02
18	71,0	-	-	-	-
Total					
Average	71,0	0,6	8,1	0,03	0,02
11	12	13	14	15	16
Slag					
Cr_2O_3	CaO	MgO	Al_2O_3	FeO	SiO_2
9,2	6,8	31,7	15,1	1,3	32,9
11,0	15,3	27,5	12,2	1,0	30,9
12,9	9,1	28,7	13,2	1,0	32,0
8,7	6,7	31,7	16,4	0,9	33,8
8,3	8,5	30,3	14,8	1,4	34,5
6,6	6,4	33,9	16,5	0,9	34,4
7,6	4,7	34,1	17,0	0,9	33,5
8,1	4,3	31,2	19,9	1,0	33,4
5,8	5,4	33,6	19,1	0,7	33,5
6,4	5,3	30,9	19,4	1,3	34,4
9,3	5,8	31,2	16,9	1,8	32,2
5,7	4,4	34,3	18,1	1,3	34,2
7,2	4,4	36,8	17,2	2,4	30,4
10,0	4,4	35,4	15,6	0,7	32,2
10,2	5,2	36,1	16,7	0,9	29,5
10,0	5,0	33,8	16,3	1,4	31,6
11,0	32,3	19,2	8,5	0,7	29,2
10,4	27,3	21,8	9,2	0,8	30,0
8,8	9,0	31,2	15,7	1,1	32,4

№	Fe	Metal weight kg	Chrome weight kg	Iron weight kg
1	7	8	9	10
1	21,8	395,0	277,5	86,2
1	19,3	501,0	362,2	96,5
2	22,1	723,0	497,9	160,1
3	19,5	138,0	99,1	27,0
4	20,0	513,0	364,6	102,6
5	20,6	330,0	233,7	68,1
6	19,3	214,0	153,7	41,3
7	20,1	314,0	222,9	63,1
8	20,3	280,0	197,6	56,8
9	20,9	808,0	569,0	169,0
10	20,7	264,0	186,1	54,5
11	20,6	520,0	367,4	106,9
12	20,4	434,0	307,0	88,5
13	20,7	568,0	402,8	117,7
14	18,6	558,0	405,2	104,0
15	19,6	425,0	302,0	83,5
16	20,0	678,0	483,5	135,9
17	20,3	792,0	562,2	160,5
18	364,9	8455,0	5994,4	1722,2
Total	20,3	469,7	333,0	95,7
Average	17	18	19	20
№	Slag weight / kg	Chrome weight / kg	Iron weight / kg	Slag ratio
1	102,0	6,4	1,0	0,3
1	138,0	10,4	1,1	0,3
1	161,0	14,2	1,2	0,2
2	220,0	13,1	1,5	1,6
3	31,0	1,8	0,3	0,1
4	150,0	6,8	1,0	0,5
5	52,0	2,7	0,4	0,2
6	81,0	4,5	0,7	0,3
7	94,0	3,7	0,5	0,3
8	230,0	10,1	2,3	0,3
9	90,0	5,7	1,3	0,3
10	118,0	4,6	1,2	0,2
11	38,0	1,9	0,7	0,1
12	360,0	24,6	2,0	0,6
13	194,0	13,5	1,4	0,3
14	153,0	10,5	1,7	0,4
15	251,0	18,9	1,4	0,4
16	168,0	12,0	1,0	0,2
17	2631,0	165,3	20,4	
18	146,2	9,2	1,1	0,4

Table 8 **Chromium balance / kg**

Chrome input kg		Chrome output kg	
From dust	6 663,03	Metal	5 994,39
From slag	32,55	Slag	165,33
Total	6 695,58	Total	6 159,72
Residual kg			535,87
Residual %			8,00
Chromium Extraction %			89,53

Table 9 **Test metal screening results**

Initial ingots weight kg	Crushed metal by fractions / kg				Residual / kg
	0 - 10 / mm	10 - 50 / mm	50 - 150 / mm	Total	
8,460	1,40	6,50	580	8,48	+20
100 %	16,5 %	76,8 %	6,9 %	100 %	0,2 %

50 kg polypropylene bags containing either pure dust or its mixture with HCFC fines. Feeding packed charge can greatly reduce the transportation and feeding losses [12].

According to the test results, the average ingot weight amounted to 470 kg. In case of chromium extraction of 89,5 3 %, the average dust consumption for one tapping would be 525 kg. Therefore, making at least 9 tappings per day, we can expect to process over 1 600 tons of dust annually.

Consequently, the DC furnace of mentioned capacity can remelt entire amount of metal dust produced at AFP.

CONCLUSION

Semi-industrial tests have shown the possibility of HCFC smelting from ferrochrome dust in a DC furnace of DCAF-1 type.

The extraction of chromium into the metal reached 89,5 %, the balance residual for chromium was 535,87 kg (8 %) per 10 tons of dust.

Over the entire test campaign, 9 930 kg of dust, 1 220 kg of HC ferrochrome slag, 140 kg of coke were consumed. The specific power consumption was below 2 272 kWh/t. 8 455 kg of metal was produced, with the following chemical composition (mass %): Cr 70,98; C 8,09; Si 0,61; S 0,03; P 0,02, with average tapping weight of 3 310 kg. Slag output was 2 631 kg, under 0,5 slag ratio.

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